# FLOOD HAZARD EVALUATION FOR DIVIDE AND WILD CREEKS GLACIER NATIONAL PARK

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Technical Report NPS/NRWRD/NRTR-91/02

WATER RESOURCES DIVISION

National Park Service - Department of the Interior
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August 1991

United States Department of the Interior
National Park Service
Washington, D.C.

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# INTRODUCTION

Glacier National Park (GLAC) has experienced recurring flooding problems in developments located along Divide and Wild Creeks near the town of St. Mary, Montana. Park facilities along Divide Creek have flooded twice and have been threatened by flooding on several other occasions in recent years. Channel instability frequently occurs in Divide Creek during high flows and channel maintenance and debris removal has been necessary to protect park facilities. This channel work has been done in emergency circumstances during the flood events and without necessary environmental permitting. A campground located along Wild Creek, also in the St. Mary area, is being encroached upon by the creek and several camping units have been lost in recent years. Park management needs information regarding the hydrologic and hydraulic character of flooding in Divide and Wild Creeks to develop a plan for mitigating flood hazards in this area and for securing required environmental permits.

To address this need, a Task Directive was prepared in February, 1990, by the National Park Service (NPS), Water Resources Division (WRD). This Directive presents a sequence of tasks which when implemented will lead to a better understanding of the hydrologic conditions of Divide and Wild Creeks and allow park management to make informed decisions regarding the actions necessary for use of these floodplains. In August, 1990, members of the WRD visited the area and collected field information to address items in Phase I of the Task Directive. The objective of Phase I is to provide the information needed to evaluate the options for mitigation of flooding conditions. This report presents the results of Phase I of the Divide and Wild Creeks Flood Hazard Evaluation Task Directive.

# DIVIDE CREEK SITE ASSESSMENT

## Background

Divide Creek drains a watershed of approximately 13 square miles ($mi^2$) and forms a portion of the eastern boundary of the park (Figure 1). Blackfeet Indian Tribal land and the town of St. Mary, Montana are located adjacent to the park, east of the stream. Park facilities are located on an alluvial fan formed by the stream as it exits the steep mountain front. The stream in this reach is actively depositing glacial material transported from higher portions of the watershed. The sources of this material are the overly-steep moraines upstream of the fan which, by mass wasting, are able to supply virtually unlimited amounts of material. The steep slope of the channel and narrow flow area above the fan create high stream velocities and associated stream powers which enable the stream to carry large amounts of

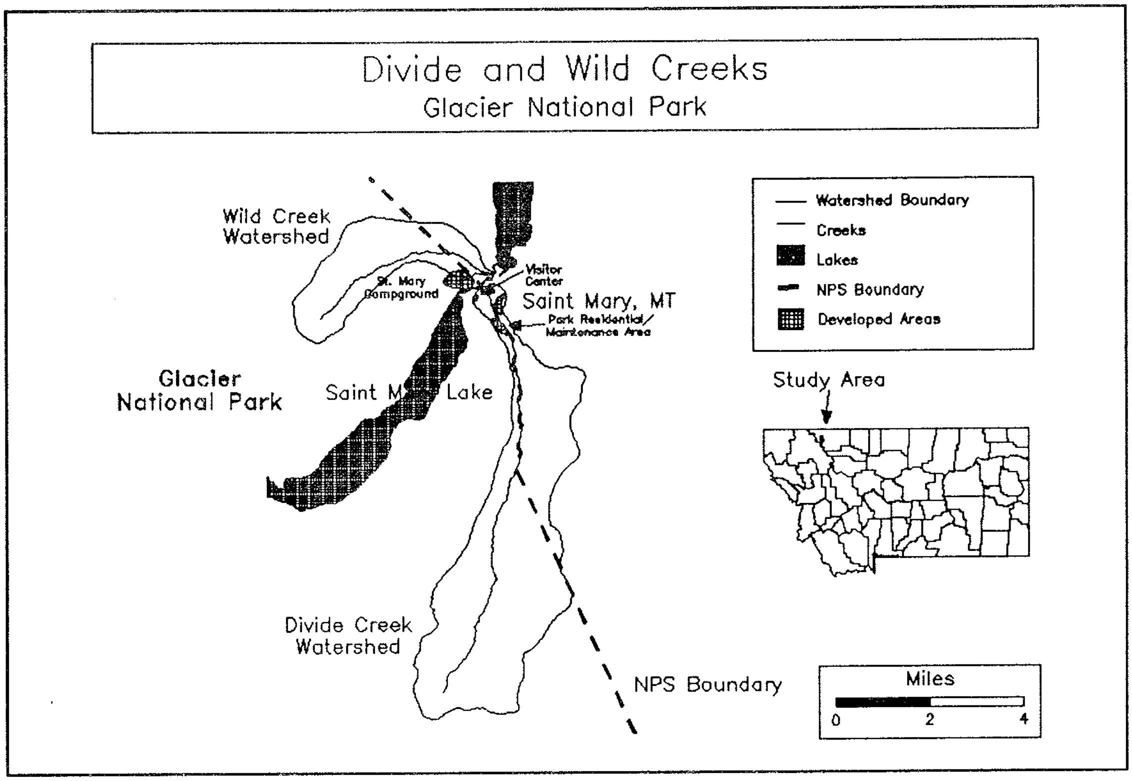


Figure 1. Study Area

sediment. The stream in the area of the fan is less steep and unconfined by canyon walls. As the stream flows across the alluvial fan, velocity is reduced and much of the sediment load is deposited. As shown on Figure 2, the stream bed of Divide Creek in the vicinity of the developed area is at nearly the same elevation as its adjoining floodplain and, as a result, any deposition of material onto the bed encourages the stream to change course and find a lower portion of the floodplain. For this reason, the stream channel is very unstable and historically has shifted over a large area extending from near the town of St. Mary (present location) to a location near the historic St. Mary Ranger Station. Review of topographic maps suggests that the Divide Creek fan extends well into St. Mary Valley and may be responsible for splitting a large prehistoric lake into the two lakes present today, Upper and Lower St. Mary Lakes.

Additional evidence of the unstable nature of Divide Creek is abundant. The hillsides surrounding Divide Creek are made up of unconsolidated and unsorted glacial till. Erosional and mass wasting features are visible from the highway leading into St. Mary. During the field trip, sites with unvegetated scarp faces several hundred feet high were visited. These sites undergo erosion on a daily basis,

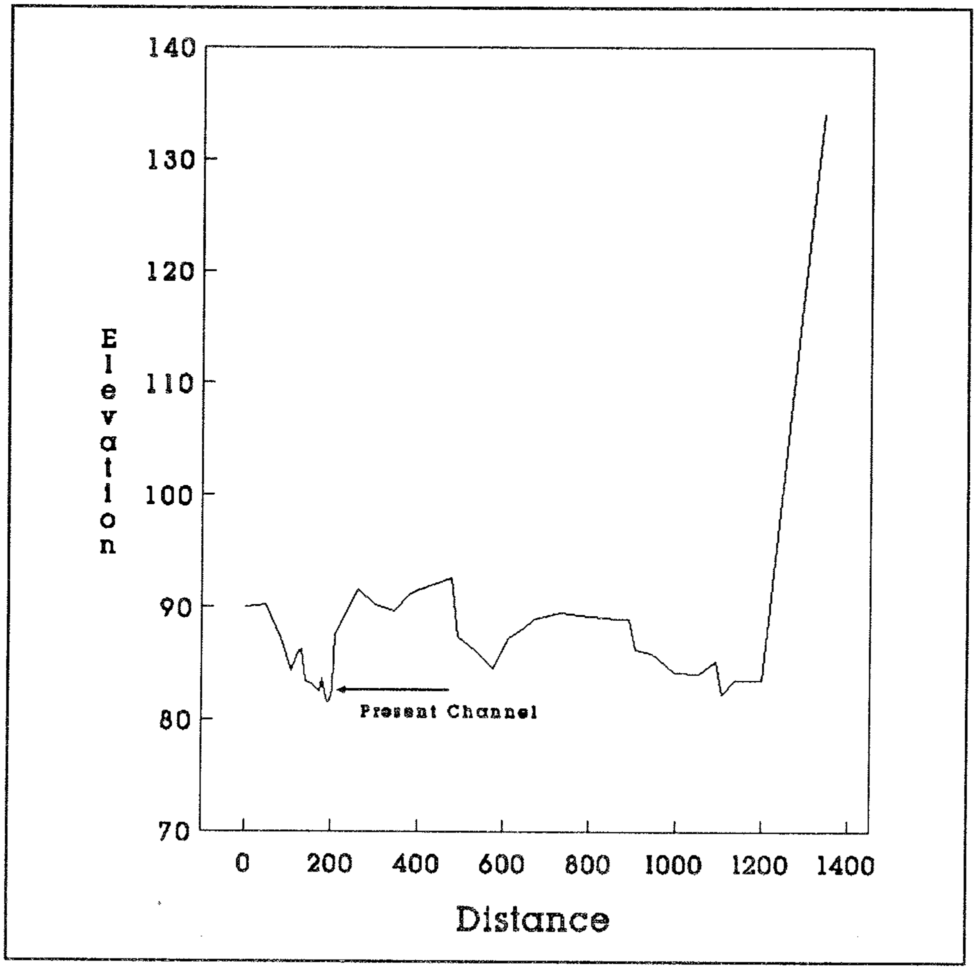


Figure 2. Profile of Divide Creek and floodplain in residential/maintenance area. Profile is perpendicular to channel, approximately 100 feet downstream of access road bridge.

however, during intense rainfall events these processes are accelerated. Recent aggradation is evident at the highway bridge where two of the three openings were nearly full of material at the time of WRD's field work was conducted. Sediment accumulation in bridge openings has taken place in a period of only two years since the last removal of material, and during a time of only average flows. During large flow events aggradation occurs at a much higher rate than during normal flow periods as evidenced by the need for sediment removal during recent floods.

## Review of Previous Work

In the early 1980s the U.S. Army Corps of Engineers (COE) performed a floodplain analysis of the area and recent management decisions regarding use of the area largely, have been based on this work. The map produced from this study shows the greater portion of the frequently flooded developed area to be outside of the base floodplain (100-year floodplain) and much of it outside the 500-year floodplain. Given the frequency of flooding in the Divide Creek floodplain in recent history, an evaluation of the methods used in the production of the COE floodplain map is warranted to reconcile the discrepancy between expected and observed flooding frequency. There are several possible explanations for this discrepancy: 1) occurrence of several improbable hydrologic events in a short time, 2) incorrect estimates of flood flow magnitudes, 3) use of invalid assumptions in hydraulic modeling, and 4) invalid interpretation of model results. Each of these potential problems were investigated and are discussed below.

The determination of whether or not several low frequency flood events have occurred in recent times is difficult. The absence of long-term gaging records makes this determination uncertain at best. No stream gaging exists for Divide Creek. Furthermore, other streams in the area that can be used for comparative purposes have only relatively short periods of record (less than 50 years). Since long-term records are unavailable, it is impossible to be certain that recent floods have been caused by improbable events. However, due to the occurrence of several floods in a relatively short period of time, it should be assumed that flooding occurs on a frequent basis in Divide Creek.

The lack of long-term gaging records makes the task of flood frequency evaluation uncertain as well. However, by looking at existing flow records from nearby streams it can be seen that peak flows are generated in this area by three distinct processes; rainfall runoff, snowmelt runoff, and runoff from rainfall on a melting snowpack. The large flood events of 1964 and 1975 appear to have been generated from rain on snow and this process is evidently responsible for causing the largest floods in the study area. Traditional means of flood frequency evaluation, e.g., log-Pearson III and other commonly used probability distributions, may not perform well in multi-process systems (U.S. Water Resources Council 1981). Therefore, it is impossible to place a large amount of confidence in flood values calculated using these methods. In the COE flood study conducted for Divide Creek, a value of 2000 cubic feet per second (cfs) was used for the base flood (100-year flood). This value was determined by application of regional regression equations published by the U.S. Geological Survey (USGS) (Omang, et al. 1983) using a watershed area computed at the point at which Divide Creek becomes the border of the park. These equations were determined by applying log-Pearson III analysis to gage records in similar watersheds in Montana. The USGS has recently updated this work with more current information (Omang, et al. 1986). When these equations are used with a slightly larger watershed area computed for the entire basin, a base flood of about 2,500 cfs is estimated. The new 100-year flood equation has a standard error of estimate of 43 percent. An independent regression analysis of area streams conducted by the authors provided an estimate of the base flood of 3,500 cfs with a standard error of the estimate of 200 percent. It is clear from the forgoing discussion that a great deal of uncertainty exists in determining flood magnitudes in this area. While it cannot be determined that the flow rates used in the previous COE study were incorrect, the use of the smallest base flood estimate among the various methods investigated in this study is non-conservative and suggests that the value used may have been too small.

The existing COE floodplain map portrays flood-prone areas assuming a stable channel. This assumption is commonly made in floodplain determinations because, in most cases, it is reasonably valid and it simplifies flow modeling. However, mapping stationary flood boundaries has little relevance in areas such as the Divide and Wild Creek alluvial fans where floodplain topography is time-dependent due to active sedimentation processes.

The interpretation of results from hydraulic modeling under the circumstances of uncertainty described above is a difficult matter. Even in the best circumstances, results from this type of modeling should *not* be considered to be highly accurate. In an unstable area with large uncertainty in estimated flood magnitudes, a very conservative delineation of flood boundaries is necessary. The Divide Creek floodplain map appears to have been prepared assuming more precision and information than the modeling technology could provide. For example, a metal floodwall is present in a portion of the study reach and is considered to influence flows in the same manner as natural floodplain topography. This assumption causes certain portions of the area to appear to be outside of floodplain boundaries. It is tenuous to assume that the floodwall will withstand the forces of flooding and will not be circumvented by upstream channel adjustments or flooding. The presence of the wall may protect against flooding (if it remains intact and is not circumvented) but does not remove these areas from the base floodplain.

In conclusion, given the frequency of flooding in the Divide Creek floodplain and the questionable nature of certain assumptions implicit in the earlier COE study, it is clear that NPS management should not consider the existing floodplain map as representing an accurate delineation of flood-prone areas. The entire extent of the alluvial fan in the area of the development should be considered within the base floodplain.

## Evaluation of Existing Flood Hazard

During August 6-8, 1990, topographic survey information was gathered for the Divide Creek floodplain including three cross sections through the maintenance and residential development, and one cross section upstream of the development in an area where the stream is presently attempting to change course (hereafter referred to as "nick point"). In addition, hydraulic information was collected relevant to the highway bridge. To gain an understanding of the present conditions in Divide Creek and to assess the opportunity for reducing flood risk by physical means, an analysis was conducted to determine flow capacity at these three locations. Using the COE water surface profile computer program HEC-2 (COE 1982), flow capacity was estimated for the present channel topography, and was re-estimated assuming sediment deposition in existing channels. Since sediment transport data is unavailable for Divide Creek, it was necessary to estimate the amount of deposition that may occur during a single large event as a basis for recalculating channel flow capacities. It is known from field observation that deposition of 2 to 3 feet is possible over a period of a few years. This is evident from the elevated streambed, filled bridge openings, and alluvial deposits in the area. The authors believe that a single large flood event could bring down an amount of material equal to several years of normal deposition. This belief is supported by the large amount of upstream sediment supply available in the form of erosion-prone steep slopes and unconsolidated, unsorted channel material. In this study, the effect of three feet of deposition in the channel is investigated. Localized areas of much higher deposition rates may occur during large flow events. For example, the bridge area would likely undergo extremely rapid deposition caused by the obstruction of flow and resulting velocity reductions in the area upstream.

Stream hydraulics were modeled using HEC-2, a water surface profile computer model developed by the Hydraulic Engineering Center, COE (US COE 1982). Flows required to reach the base and top of the floodwall assuming the present topography are estimated to be 6,000 and 16,000 cfs, respectively. Assuming 3 feet of additional deposition in the channel, the flow required to reach the base of the wall is approximately 1,500 cfs and to reach the top of the wall is about 9,000 cfs. The elevation of the floodwall is, therefore, adequate to provide a large degree of protection even with a few feet of deposition in the channel. However, the ability of the floodwall to structurally withstand the hydraulic forces exerted by high flows is questionable. Additionally, potential exists for undermining of the structure and circumvention of flow upstream. Thus, it appears that the major concerns in this area are the stability of the metal wall and preventing flow from circumventing the wall upstream at the nick point.

The presence of the floodwall increases flooding potential in the town of St. Mary by preventing Divide Creek from using a large portion of its floodplain. Structural protection is advisable on the east bank of Divide Creek to avoid transferring flooding and channel erosion problems to neighboring land owners.

The nick point is located upstream of the maintenance yard, and is an area where the stream is presently attempting to change course. Abandoned channels are present at elevations lower than some areas of the current channel (Figure 3). A dike has been built of channel material and debris to prevent the channel from changing course and utilizing the adjacent abandoned channel. This abandoned channel runs through the developed area and would cause flooding if it were reclaimed by the stream. The nick point is upstream of the floodwall so any flows

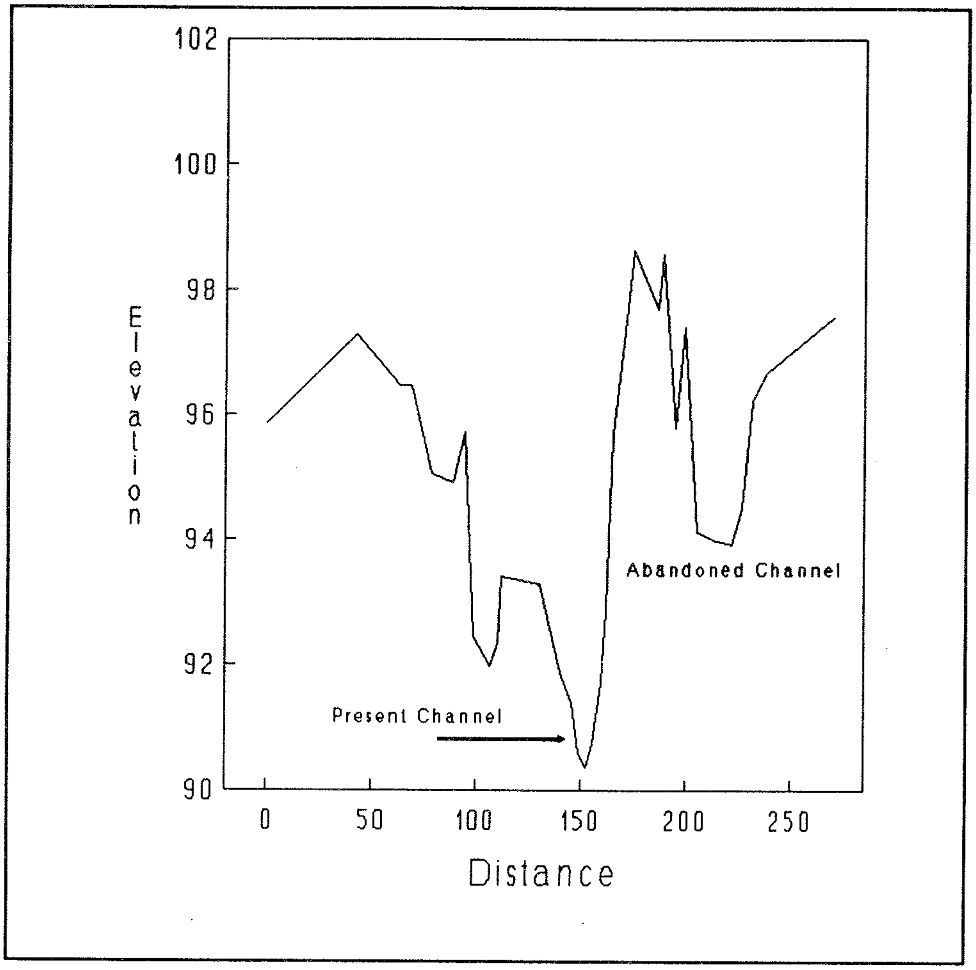


Figure 3. Profile of Divide Creek at the "Nick Point".

entering the development from the nick point would be trapped behind the floodwall and kept within the developed area.

A flow of about 3,000 cfs is predicted to reach the base of the nick point dike and would begin to cause instability due to the erosive, non-cohesive nature of the dike material. Hydraulic modeling with an assumed 3 feet of channel bed aggradation indicates a flow of about 3,000 cfs would reach the top of the dike. Due to the unconsolidated nature of the dike material, the dike could be expected to fail at flows much less than 3,000 cfs. Therefore, the combination of aggradation and high flows makes the dike a likely candidate for catastrophic failure. This type of failure would cause rapid flooding of the developed area with little or no warning and could result in loss of life and property.

The flow capacity through the bridge is estimated to be about 1,000 cfs (with the channel geometry measured in August, 1990). Any additional sedimentation under the bridge will severely reduce flow capacity. The channel upstream of the bridge was surveyed in the vicinity of the stream-side restaurant and present channel capacity in this area (assuming the levee remains intact) is estimated to be about 2,000 cfs. Placing 3 feet of deposition in the channel results in a channel capacity of about 900 cfs. Flows greater than this amount can be expected to cause flooding in the area of the restaurant. Further plugging of the bridge opening will exacerbate flooding in this area.

## Recommendations

Due to the unstable nature of the Divide Creek alluvial fan, risk from flooding cannot be eliminated at the present developed site. However, additional protection can be provided to the developments and occupants by a combination of structural improvements, regular removal of deposited channel sediments, and contingency action planning. NPS Floodplain Guidelines specify protection from the 100-year flood as the appropriate level of protection. As discussed earlier, a precise identification of the 100-year floodplain is not possible in this case. However, actions can be taken to reduce the frequency of flooding to an acceptable level and to minimize risk to life and property.

Structural improvement of the existing metal flood wall is recommended. The floodwall should be extended further upstream to the nick point and tied into the higher local topography. The floodwall, including its foundation should be evaluated for its ability to withstand the hydraulic forces of a design flood, such as the 100-year flood, and improved if necessary. Private property, east of the channel, should also be protected by an appropriately designed structure. The highway bridge should be enlarged or replaced by a bridge with larger flow capacity.

Maintaining channel capacities on a regular basis by removing accumulated sediment is the most important factor in reducing the flood hazard at Divide Creek. Since Divide Creek is an aggrading system, it continuously loses capacity to convey flow. It can be expected that the developments at Divide Creek will become increasingly more susceptible to flooding at ever lower flow levels if the channel is allowed to aggrade. A plan needs to be implemented with appropriate environmental permitting to maintain a channel that will have the ability to hold at least moderate flow events such as the 10- to 25-year flows. Minimum channel elevations and cross-sectional areas can be designed according to such criteria. These elevations and areas will then have to be maintained on an annual basis. This work could be completed each fall in anticipation of the next years high flows. All work should be thoroughly coordinated with the state of Montana to insure adequate permitting is obtained and any adverse environmental impacts minimized.

A contingency action plan should be developed and put into action anytime potential for flooding exists. Observation of unusually heavy rainfall or a forecast for the same should trigger monitoring of structural facilities. Knowledge of current watershed conditions such as snowpack or rain-saturated soils and current river stage can be factored into an assessment of flood potential. An evacuation plan should be made available to all residents and implemented when warranted.

Each of these steps will require additional study to develop design criteria and obtain proper permitting. It is recommended that the NPS consider acquiring outside expertise such as the COE to assist in developing design criteria and in the permitting process. Design criteria should contain estimates of the amount of material to be moved and cost estimates for improvements. The flood hazard mitigation plan should involve all involved parties including the town of St. Mary and the Blackfeet Indian Tribe.

## Summary

Flood hazard mitigation along Divide Creek will require a variety of actions including periodic channel maintenance and contingency planning. Long range costs will continue for as long as the development at Divide Creek exists. Because of the extremely unstable nature of Divide Creek, complete elimination of all risk of future flooding can never be achieved, however, the steps recommended above will reduce the frequency of future flooding and associated risk.

# WILD CREEK SITE ASSESSMENT

## Background

The Wild Creek watershed is a small basin (approximately 4 $mi^2$) located immediately north of Divide Creek. Similar to Divide Creek it has developed an unstable alluvial fan. St. Mary Campground is located on the fan within the park and a few other developments are present on adjoining property. In recent years Wild Creek has shifted its course somewhat and has rendered several camping units unusable. Secondary channels are present and are used at higher flows. The main stream channel appears to be ready to shift further west toward the camping area. This may be made more likely by the placement of small levees on the east side of the stream. No previous flood studies are known to have been conducted for Wild Creek.

## Evaluation of Existing Flood Hazard

During the field trip two representative cross sections were surveyed through the floodplain in the campground area. One of these cross sections is shown in Figure 4. These cross sections reveal that much of the campground is well above

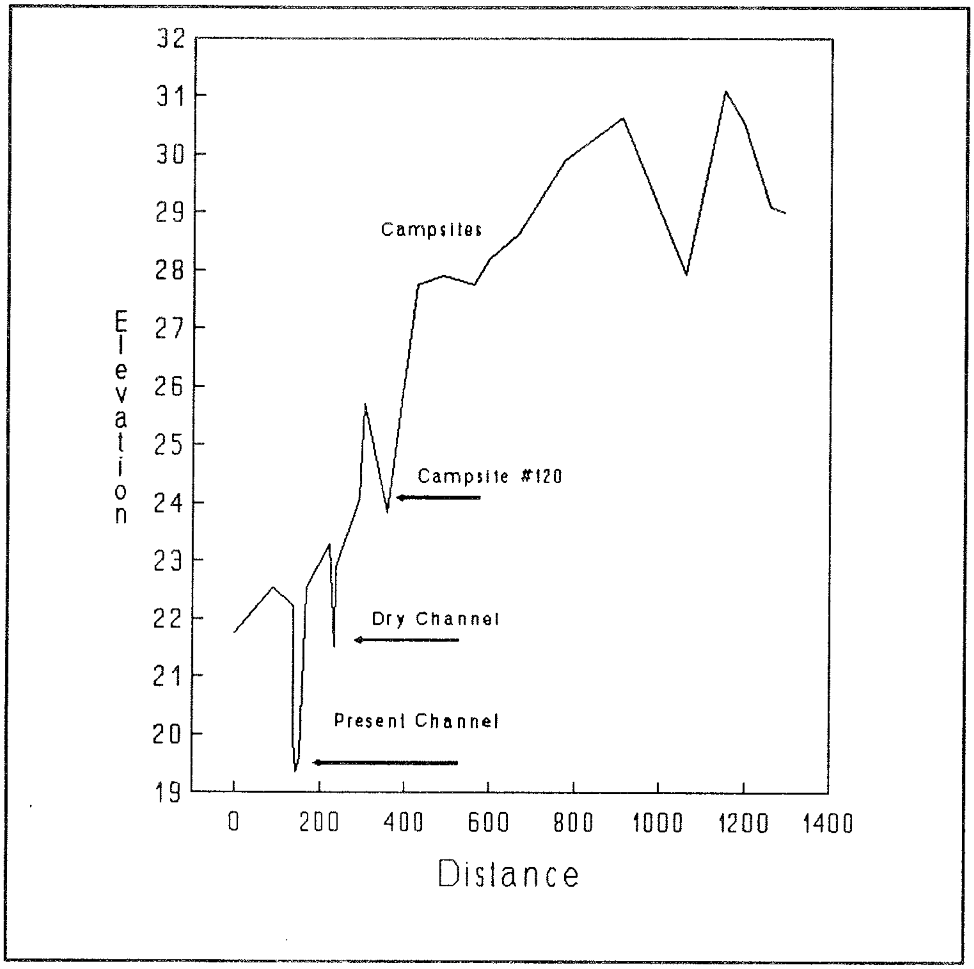


Figure 4. Profile of St. Mary Campground and Wild Creek

the Wild Creek channel and in little danger of flooding. Portions of the campground located near the channel, however, are susceptible to flooding particularly if aggradation encourages stream channel instability.

Hydraulic modeling was performed using HEC-2 to estimate the flow capacity of the existing channel. The present channel in the vicinity of the campground is estimated to be capable of passing approximately 500 cfs. This flow value is much lower than estimates of the 100-year flood which range from 980-1,350 cfs as derived from the same methods used in the Divide Creek analysis. With sediment deposition in the channel, flooding would occur at a much lower discharge indicating that flow outside of the channel can be expected on a fairly frequent basis in this area. Evidence of overbank flow is present in the eastern portion of the campground where an overflow channel has recently cut into the development. This channel directs flow toward the lower-lying area in the southeast part of the campground and may cause flooding in this area. Additional survey information is needed to identify the areas susceptible to flooding and/or channel changes. However, traditional floodplain mapping would be of limited use since the area is geomorphically unstable.

## Recommendations

Structural confinement of Wild Creek was not investigated in this study because of the limited level of development present along the creek. If NPS management wishes to stabilize the channel in a particular location, actions similar to those suggested for Divide Creek would be necessary.

Hazard to humans from flooding can be mitigated non-structurally by not using the flood prone areas of the campground during the peak snowmelt season. Also, the stream should be observed during unusually large summer thunderstorms and the lower portion of the campground evacuated when streamflow rises rapidly.

## Summary

Park management can expect channel instability and low-lying terrain flooding to continue in the St. Mary Campground because of the natural instability of alluvial fans. Few structures exist in the area and the park investment is much less than on the Divide Creek fan and therefore, structural control of the stream may not be warranted. The campsites nearest the channel need to be monitored for encroachment by the stream channel. As the channel continues to migrate westward, these campsites will eventually become more susceptible to flooding and may have to be taken out of service. In the near term, use may need to be limited at these sites during high flows or during periods of potential high flow. During such time, the stage of Wild Creek should be monitored and appropriate actions taken when channel instability is likely.

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NPS D-269 August 1991